

Adiabatic three-wave symmetric volume hologram

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A transmission hologram with two symmetrically oriented volume gratings is considered in the regime of diffraction of wave *A* into wave *B* via intermediate weakly excited wave *C*. Adiabatic regime of highly efficient diffraction has the advantage of very low sensitivity to the strength of the gratings.

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Transmission volume holograms allow for the diffraction efficiency $\eta = [\sin(M)]^2$, [1-3], which can reach 100%, if the hologram strength $M = \kappa L \equiv \pi n_1 L / \lambda_{\text{vac}}$ equals $\pi/2 = 1.57$, or $3\pi/2$, or $5\pi/2$, etc. Here L is the effective interaction length, $L = L_z / [\cos(\theta_{A,\text{medium}})\cos(\theta_{B,\text{medium}})]^{0.5}$, and modulation of refractive index in the volume grating is assumed to be $\delta n = n_1 \cos(\mathbf{Q} \cdot \mathbf{R})$; λ_{vac} is the wavelength of light in vacuum, $\theta_{A,B,\text{medium}}$ are the angles of propagation of *A*- and *B*-waves from *z*-axis in the medium. Disadvantage of this simple volume hologram is rather high sensitivity of η to the hologram strength $M = \kappa L$.

A process has been suggested and studied in Nonlinear Optics, STIRAP: Stimulated Raman Adiabatic Passage, [4], which allows for efficient transfer of population between two Raman sublevels via transition through third resonant level. We suggest in this talk to apply that idea to holography. Namely, we consider a volume hologram with two gratings,

$$\delta n = n_{AC}(z) \cdot \cos(\mathbf{Q}_{AC} \cdot \mathbf{R}) + n_{BC}(z) \cdot \cos(\mathbf{Q}_{BC} \cdot \mathbf{R}), \quad (1)$$

in assumption that Bragg condition is satisfied for both processes, $\mathbf{A} \exp(i\mathbf{k}_A \cdot \mathbf{R}) \rightarrow \mathbf{C} \exp(i\mathbf{k}_C \cdot \mathbf{R})$ and $\mathbf{C} \exp(i\mathbf{k}_C \cdot \mathbf{R}) \rightarrow \mathbf{B} \exp(i\mathbf{k}_B \cdot \mathbf{R})$. Here *C* is the intermediate wave, see Figure 1.

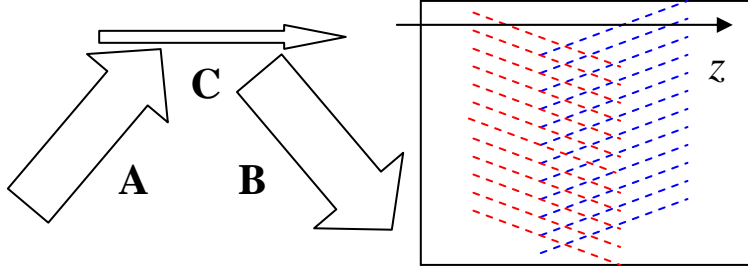


Figure 1.

Coupled wave equations are

$$dA/dz = i\kappa_{AC}(z)C(z) + i\mu AC(z), \quad dB/dz = i\kappa_{BC}(z)C(z) - i\mu AC(z), \quad dC/dz = i\kappa_{AC}(z)A(z) + i\kappa_{BC}(z)B(z). \quad (2)$$

Here $\mu = -\delta\theta_{\text{air}}[\pi\cos(\theta_{\text{air}})/n\lambda_{\text{vac}}]/[\cos(\theta_{\text{medium}})]^{0.5}$ is the parameter characterizing the detuning of the incidence angle of *A*-wave from exact Bragg angle. This parameter μ enters into *A*- and *B*-equations with the opposite sign in our symmetric configuration. Counterintuitive STIRAP-type configuration requires that the *BC*-grating is “turned on” closer to the input of *A*-wave, *AC*-grating is “turned on” closer to the output of *B*-wave, and two gratings do overlap in the hologram.

We have integrated our system of coupled wave equations for several particular profiles of the coupling coefficients $\kappa_{AC}(z)$ and $\kappa_{BC}(z)$ in assumption of the fixed hologram strengths,

$$M_{AC} = \int \kappa_{AC}(z) dz, \quad M_{BC} = \int \kappa_{BC}(z) dz. \quad (3)$$

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Very favorable profile of the coupling coefficients was found:

$$\kappa_{BC}(z) = M_{BC}[\cos(\pi z/2L_z)]^2 \cdot (2/L_z), \quad \kappa_{AC}(z) = M_{AC}[\sin(\pi z/2L_z)]^2 \cdot (2/L_z). \quad (4)$$

The dependence of the diffraction efficiency $\eta(A \rightarrow B)$ on the hologram strengths M_{AB} and M_{BC} in the intervals from 0 to 15 is depicted at the Figure 2 for the case of perfect Bragg matching, i.e. at $\mu = 0$.

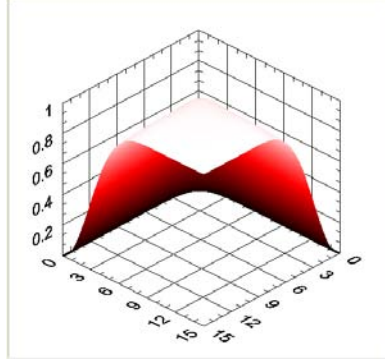


Figure 2.

Other profiles have also been studied, with somewhat worse results. We have also studied the dependence of the amplitude and phase of the output B-wave as a function of hologram strengths at non-zero Bragg detuning values. It turns out that the diffraction efficiency is not affected strongly by small Bragg detuning, while the phase of the output B-wave is quite sensitive to such detuning.

The results of calculations of angular and spectral selectivity of our three-wave symmetric and asymmetric holograms will be also presented in the talk.

We believe that the volume phase holograms in photo-thermo-refractive glasses, [5], may greatly benefit from the use of this STIRAP-type configuration.

To conclude, the configuration of transmission volume hologram of $A \rightarrow B$ diffraction via intermediate weakly excited wave C has been suggested and studied via numerical integration of coupled wave equations. Adiabatic $A \rightarrow B$ transfer of energy takes place for the appropriate z -profile of the gratings, and the diffraction efficiency turns out to be insensitive to the variations of the strength values of the gratings.

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